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EFFECT ON INSECT SURVIVAL, RHEOLOGICAL CHARACTERISTICS, AND BAKING PROPERTIES OF FLOUR CANNED IN AIR OR IN NITROGEN ATMOSPHERES

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Project reference: PE 728012-12

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UNITED STATES ARMY
NATICK LABORATORIES
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Eggs, larvae, and adult insects (Tribolium castaneum) were hermetically canned with flour in air or in nitrogen atmospheres and stored at 21°C. and 38°C. After 6 months storage, it was found that none of the insects had passed through more than two stages of metamorphosis, and most died without a single stage change. No significant rheological change occurred in doughs prepared from untreated flour and flour packed in different atmospheres. Rheological differences were noted in all samples as a result of storage temperature.

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Baking	7					
Baking Properties	7					

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FOREWORD

Wheat flour currently packaged in multi-walled paper bags has suffered major losses due to heavy insect infestation. This project was undertaken to evaluate the effectiveness of hermetically sealing flour in an air or nitrogen atmosphere as an insect control measure and to determine its effect on dough rheology and baking qualities.

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ABSTRACT

Eggs, larvae, and adult insects (*Tribolium castaneum*) were hermetically canned with flour in air or in nitrogen atmospheres and stored at 21°C. and 38°C. After 6 months storage, it was found that none of the insects had passed through more than two stages of metamorphosis, and most died without a single stage change. No significant rheological change occurred in doughs prepared from untreated flour and flour packed in different atmospheres. Rheological differences were noted in all samples as a result of storage temperature.

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INTRODUCTION

Insects have been known to invade the soldier's person, making life uncomfortable, and to compete very successfully for his food. Reports from Korea and Vietnam indicated heavy infestation of wheat flours. It was reported that 40% of the weight of flour consieted of insects in various stages of development in one lot in Vietnam. Thousands of dollars worth of infested flour wae destroyed, and a great deal more was used only to be discarded by the troops who knew of the flour infestation problem. The rupturing of 80 to 100% of bage during ehipments of flour is not uncommon, thus rendering package treatment for insect resistance lese effective.

Continued reports of insect infestation of flour with attendant economic losses coupled with a dearth of literature on the subject indicated the need for a basic study on the survival of insects and their effect on baking characteristics. Experience with canned cake mixes known to be virtually insect free, and general knowledge of insect biology gave rise to the postulate that a limited oxygen supply actually restricts insect growth in these canned items (Chapman, 1921, 1926; Dean, 1913; Doane, 1918; Howe, 1956). Since flour for the military is often stored for a much longer time than commercial flour, the effect of long etorage on baking characteristics is also of interest.

METHODS AND MATERIALS

Number 10 cans filled with 4 pounds of hard wheat flour were infested with 50 insects, Tribolium castaneum (Herbst), of a particular life stage, i.e. egg, larva or adult. The insects were added to the top of the contents after filling. A single test unit consisted of six infested cans, two uninfested cans, and three uninfested five pound paper packets. Of the six infested cans, three were air-packed by hermetically sealing under atmospheric conditions and three were nitrogen-packed by first evacuating to 20 inches of mercury and then flushing back to atmospheric pressure with nitrogen. One control can with uninfested flour was given each treatment. The test cans were stored at 21°C. and 38°C. The paper packets were stored at 4.5°C. and 21°C.

Farinograph curves were obtained on the flour initially and after three and six months storage except for the infested flour which was tested after six months storage. The following data were recorded (Bequette et al, 1960; Trum and Rose, 1964):

1. Moisture content
2. Absorption (14% moisture basis)
3. Arrival time (minutes)
4. Departure time (minutes)
5. Stability (minutes)
6. Peak time (minutes)
7. Mixing Tolerance Index (Brabender units)
8. Tweny Minute Drop (Brabender units)

Baking tests were performed on the noninfested samples after six months storage. Baking data on infested flour were not obtained since a similar study involving T. castaneum was previously performed and reported (Smith et al., 1971).

Dough was prepared by mixing the flour to be tested with other ingredients in the following proportions:

Ingredient	Weight Kg.
Flour	1.36
Yeast, Active, Dry	0.03
Water	0.90
Nonfat dry milk	0.08
Sugar	0.07
Shortening	0.07
Salt	0.02

After mixing, the dough was placed in a "Fermentation Chamber," maintained

at a constant temperature of 35.5° ± 1°C. and 92% R.H. until the dough had risen 0.95 cm (3/8 in.) above the center of the pan. The dough was baked for 25 minutes in a rotating oven at 220°C. (425°F.) and then removed for cooling and slicing. The sliced bread was placed in plastic bags, air was removed, and the bags were sealed. Baking quality data were obtained subjectively by scoring the individual loaves for certain properties, as shown in Table 1. Evaluations were made within 24 hours of baking.

Table 1 - Method of Evaluating Bread Properties

Property	Numerical Rating	Penalties for:
Specific Volume	0-10	Too small
Crust Color	0-8	Not uniform Light Dark Dull Streaked
Symmetry	0-3	Low end Protruding crust Shrunken side Flat top
Evenness of Bake	0-3	Light side Light bottom Light end Dark bottom Spotty bottom
Crust Character	0-3	Thick Hard Brittle
Break and Shred	0-3	One side only No shred Shell unsufficient
Grain	0-15	Coarse Not uniform Thick cell walls
Crumb Color	0-10	Gray Dark Streaky Dull
Aroma	0-10	Musty Flat Foreign Sharp
Keeping Quality	0-10	Stale Dry
Texture	0-10	Rough Doughy Crumbly
TOTAL SCORE POSSIBLE	85	

RESULTS AND DISCUSSION

After 6 months of storage at 21°C. and 38°C. in air and nitrogen pack, the results of insect infestation were as shown in Table 2.

Table 2 - Insect Population
in Flour After 6 Months Storage at 21°C. and 38°C.

Code*	Storage Temp. °C.	Insect Population
6 AE	21	Some eggs hatched - but all larvae were dead
6 AE	38	" " "
6 AL	38	Larvae - dead - a few adults, all dead, no eggs present
6 AL	21	" "
6 AA	21	All adults dead - some eggs present, but no larvae
6 AA	38	" " "
6 NE	21	No eggs hatched
6 NE	38	" " "
6 NL	21	All larvae dead
6 NL	38	" " "
6 NA	21	All adults dead - some eggs present, but no larvae
6 NA	38	" " "

*Code Explanation:

First character = months of storage
Second " = Air (A) or Nitrogen (N) pack
Third " = Eggs (E), Larvae (L) or Adult (A)

Temperature conditions, i.e. 21°C. or 38°C. had no effect on life stages, e.g. whatever happened at 21°C. also happened at 38°C. In those cans initially infested with eggs only, some eggs hatched in the cans packed under air atmosphere, but none under nitrogen atmosphere.

In those cans infested with larvae only, some larvae became adults in the air atmosphere, but none in the nitrogen atmosphere. In those cans infested with adults only, eggs were laid under both atmospheres, but none hatched during the test. Subsequent to the test, all unhatched eggs were kept under ideal conditions to determine viability; none of these eggs hatched. The nitrogen atmosphere,

therefore, seems to have had a detrimental effect on all the life stages to T. castaneum. The air atmosphere allowed for some single stage changes but the oxygen present seemed inadequate to support complete larval molting.

Rheological examinations of the dough are shown in Tables 3 through Table 7. From these data it appears that the storage temperature effect was of major significance and was significant in both atmospheres (Table 8). Code numbers 1 - 8 in all tables indicate the following:

1. % H_2O
2. Abs (14% MB)
3. Arrival Time (min.)
4. Departure (min.)
5. Stability (min.)
6. Peak Time (min.)
7. Mixing Tolerance Index (Brabender Units)
8. Twenty Minute Drop (Brabender Units)

The moisture content of flour is required to compute the absorption, but does not necessarily affect other characteristics. A decrease in absorption of flour indicates a lowering of protein quality which adversely affects baking properties. A decrease in tests 3, 4, 5, 6 and 7 or an increase in test 8 indicates a reduction in baking and mixing tolerance. These changes do not necessarily correlate with baking quality as long as the baker makes adjustments in his procedure. As these changes progress, however, procedural adjustments no longer fully compensate for them and losses in specific valume and inferior grain and texture occur.

Table 3 - Rheological Characteristics of Flour Stored in Paper Sacks

Test Code	Initial	3 Months 21°C.*	6 Months 21°C.	3 Months 21°C. plus 3 Months 4.5°C. **
1.	12.8	12.5	11.59	15.80
2.	67.0	60.6	61.6	60.3
3.	3.0	2.0	1.5	1.3
4.	15.5	13.0	10.0	12.0
5.	12.5	11.0	8.5	10.7
6.	9.0	4.0	2.3	2.5
7.	20.0	10.0	20.0	0.0
8.	55.0	70.0	90.0	80.0

* At this time some of this flour was placed under 4.5°C. refrigeration.

** This flour picked up moisture from the air and the outside of the package was covered with mold. Note the high moisture content.

Table 4 - Rheological Characteristics of Flour after 3 Months Storage-Canned in Air or Nitrogen

	Nitrogen Pack		Air Pack	
Test Code	21°C.	38°C.	21°C.	38°C.
1.	12.8	12.6	13.1	13.0
2.	61.5	61.3	60.6	60.4
3.	2.0	2.0	2.0	2.0
4.	14.5	17.0	13.0	10.0
5.	12.5	15.0	11.0	8.0
6.	7.0	3.0	8.0	3.0
7.	20.0	10.0	30.0	20.0
8.	55.0	45.0	80.0	105.0

Table 5 – Rheological Characteristics of Flour after 6 Months Storage–Canned in Air or Nitrogen

	Nitrogen Pack		Air Pack	
Test Code	21°C.	38°C.	21°C.	38°C.
1.	12.91	12.87	13.25	13.42
2.	62.5	62.1	60.9	63.3
3.	1.8	1.7	1.3	1.0
4.	9.0	5.0	9.0	2.0
5.	7.2	3.3	7.7	1.0
6.	3.0	2.8	2.5	1.5
7.	30.0	40.0	40.0	100.0
8.	90.0	35.0	110.0	80.0

Table 6 – Rheological Characteristics of Flour after 6 Months Storage–Canned With Insects in Air

	Adults		Larvae		Eggs	
Test Code	21°C.	38°C.	21°C.	38°C.	21°C.	38°C.
1.	12.50	11.35	12.87	11.78	12.85	12.68
2.	61.5	62.7	61.7	62.6	61.3	63.2
3.	1.4	1.2	1.5	1.0	1.2	1.2
4.	14.0	3.0	13.0	3.2	14.0	3.0
5.	12.6	1.8	11.5	2.2	12.8	1.8
6.	2.3	1.7	2.5	1.7	2.3	1.7
7.	30.0	70.0	30.0	45.0	30.0	85.0
8.	65.0	85.0	90.0	70.0	70.0	60.0

Table 7 - Rheological Characteristics of Flour after 6 Months Storage-Canned With Insects in Nitrogen

Test Code	Adults		Larvae		Eggs	
	21°C.	38°C.	21°C.	38°C.	21°C.	38°C.
1.	12.22	11.81	12.48	11.43	12.71	12.54
2.	61.8	62.3	61.5	61.5	62.7	62.8
3.	1.0	1.0	1.5	1.4	1.2	1.2
4.	14.0	4.0	11.0	3.5	12.4	3.3
5.	13.0	3.0	9.5	2.1	11.2	2.1
6.	2.0	1.7	2.8	2.0	2.2	2.1
7.	20.0	70.0	0.0	70.0	25.0	80.0
8.	80.0	70.0	70.0	70.0	90.0	75.0

Table 8 - Statistical Treatment of Variables

	Canned Flour Control					
	A	B	C	AB	AC	BC
Percent Water	NS	NS	NS	*	NS	NS
Arrival Time	**	*	NS	*	NS	NS
Department Time	*	NS	NS	NS	NS	NS
Stability	*	NS	*	NS	NS	NS
Peak Time	**	NS	**	NS	**	NS
MTI	NS	NS	NS	NS	NS	NS
TMD	NS	NS	NS	NS	NS	NS
	Canned Flour With Insects					
	A	B	C	AB	AC	BC
Percent Water	*	**	**	NS	NS	**
Arrival Time	NS	NS	NS	NS	NS	NS
Departure Time	NS	NS	**	NS	NS	NS
Stability	NS	NS	**	NS	NS	NS
Peak Time	NS	NS	**	NS	NS	NS
MTI	NS	NS	**	NS	NS	NS
TMD	NS	NS	NS	NS	NS	NS

Continued on page 10

Canned Flour With Insects (Continued)

Interactions

A Storage Time (Initial vs 3 and 6 months)
B Atmosphere (N_2 vs Air)
C Temperature (21°C. vs 38°C.)

Code Explanation:

NS No significance
* Significant at .05 level
** Significant at .01 level

Table 9 - Baking Quality of Flour After 6 Months Storage

Sample	Loaf No.	Wt. (gms)	Volume (cc)	Specific Volume (SV)	Average (SV)	Bread Score
Air 21°C.	1a	438	2245	5.12	5.15	80
	1b	431	2245	5.20		
	1c	447	2300	5.14		
Air 38°C.	2a	445	1840	4.13	4.24	71
	2b	441	1890	4.28		
	2c	458	1975	4.31		
$N_2$21°C.	3a	449	2250	5.01	4.90	80
	3b	448	2135	4.76		
	3c	445	2200	4.94		
$N_2$38°C.	4a	458	2200	4.80	4.65	79
	4b	462	2135	4.62		
	4c	460	2085	4.35		
Paper 4.5°C.	5a	437	2185	5.00	5.15	81
	5b	439	2290	5.22		
	5c	440	2300	5.23		
Paper 21°C.	6a	450	2300	5.11	5.05	81
	6b	444	2225	5.01		
	6c	446	2240	5.02		

Baking quality of the air and nitrogen packed uninfested flour stored for six months at 21°C. and 38°C. was compared to flour stored in paper packets at 4.5°C. and 21°C. for six months. Results are shown in Table 9. A loss in specific volume was noted in the 38°C. storage samples. Bread score in the 38°C. air pack sample was significantly lower than all other samples. Other results show no significant differences. The paper packets stored at 4.5°C. developed a heavy growth of green mold on the outside of the package which imparted a musty odor and flavor to the flour. The moisture content of this sample increased from 12.80 to 15.80%.

CONCLUSION

Hermetically canning flour in an air or nitrogen atmosphere effectively controls eggs, larvae, and adult T. castaneum present in the flour at the time of canning. It also prevents moisture transfer and further infestation of the flour thus increasing flour shelf life.

Dough rheology and bread quality are not adversely affected by canning the flour in an atmosphere of air or nitrogen, but are affected by storage temperature. These facts must be weighed against the disadvantage of a substantial packaging cost increase for rigid metal cans.

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